In [2]:

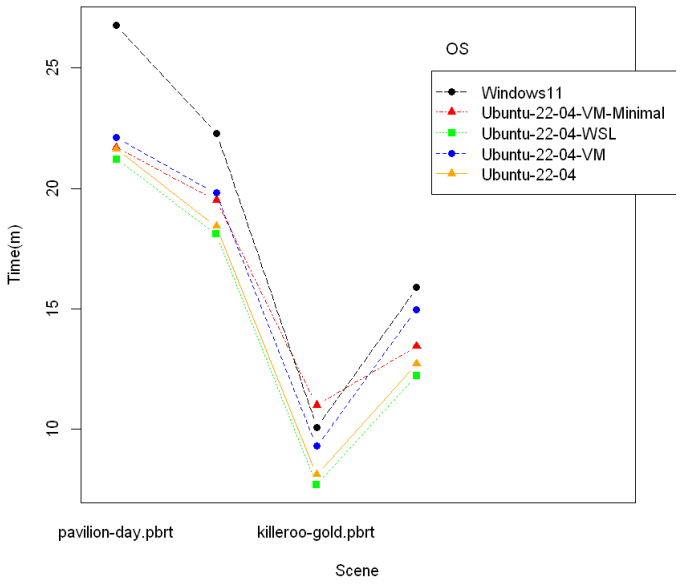
```r
# 1. Carga inicial de datos.
if(!require(psych)){install.packages("psych")}
if(!require(FSA)){install.packages("FSA")}
if(!require(ggplot2)){install.packages("ggplot2")}
if(!require(car)){install.packages("car")}
if(!require(multcompView)){install.packages("multcompView")}
if(!require(lsmeans)){install.packages("lsmeans")}
if(!require(rcompanion)){install.packages("rcompanion")}

# Lectura de datos
Data <- read.csv2("updated_file.csv", sep = ",", header = TRUE)


Data$Time <- as.numeric(Data$Time)
Data$OS <- factor(Data$OS, levels = unique(Data$OS))
Data$Scene <- factor(Data$Scene, levels = unique(Data$Scene))
Data$Acc.Int <- factor(Data$Acc.Int, levels = unique(Data$Acc.Int))


# 2. Verificación de la lectura de datos.
library(psych)
headTail(Data)
str(Data)
summary(Data)


# 3. Gráfico simple de interacción.
# Variable dependiente: Time
# Variables independientes: OS y Scene.
interaction.plot(x.factor = Data$Scene,
 trace.factor = Data$OS,
 response = Data$Time,
 fun = mean,
 type = "b", col = c("black", "red", "green", "blue", "orange"),
 pch = c(19,17,15,19,17),
 fixed = TRUE, xlab= "Scene", ylab="Time(m)", trace.label="OS",
 leg.bty = "o")


# Variable dependiente: Time
# Variables independientes: OS y Acc.Int.
interaction.plot(x.factor = Data$Acc.Int,
 trace.factor = Data$OS,
 response = Data$Time,
 fun = mean,
 type = "b", col = c("black", "red", "green", "blue", "orange"),
 pch = c(19,17,15,19,17),
 fixed = TRUE, xlab= "Accelerator-Integrator", ylab="Time(m)", trace.label="OS",
 leg.bty = "o")

# 4. Modelo lineal
model <- lm(Time ~ Scene * OS * Acc.Int, data = Data)

# 5. Evaluación de los supuestos
x <- residuals(model)
library(rcompanion)
par(mfrow = c(2, 1))
plotNormalHistogram(x, xlab="Time(m)")
qqnorm(resid(model), main = "Normal Q-Q", xlab = "Theoretical Quantiles", ylab = "Standarized residuals")
qqline(resid(model), col = "red", lwd = 2)
par(mfrow = c(1, 1))
plot(fitted(model), residuals(model))
plot(model)
# La normalidad es debatible, sin embargo igual se puede apreciar.
# En el gráfico de dispersión no se observa un patrón claro entre los datos, del mismo modo se procede a rea
# prueba Levene para confirmar homocedasticidad.

leveneTest(Time ~ Scene * OS * Acc.Int, data = Data)
# La prueba Levene retorna un P-Value 0.9856, lo que sugiere homocedasticidad en los datos.

# Debido a que la normalidad es el supuesto más permisivo y que tanto el gráfico de dispersión y la prueba L
# sugieren la presencia de homocedasticidad en los datos, no se procede a realizar transformación de los mis
# Para no incurrir en el riesgo de acercar mucho los datos innecesariamente. (No incurrir en error tipo-II)

# 6. ANOVA
```

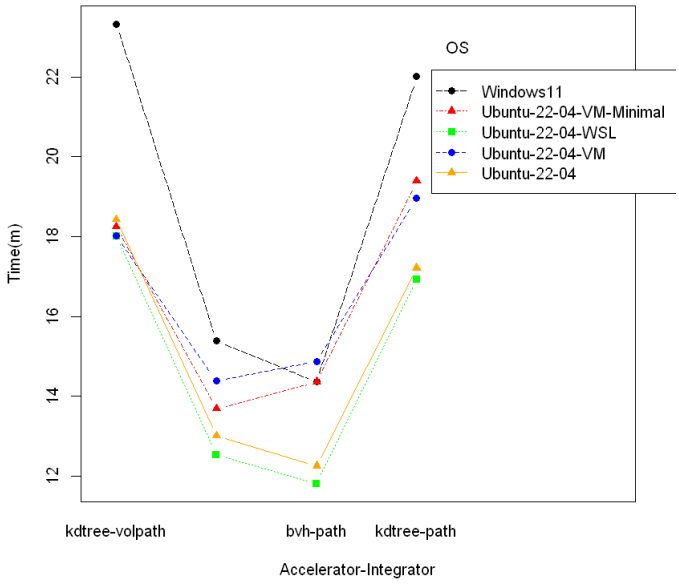
```r
library(car)
Anova(model, type = "II")

# 7. Gráfico bigotes con error estándar OS
Sum <- Summarize(Time ~ OS, data=Data, digits=3)
Sum$se <- Sum$sd / sqrt(Sum$n)
Sum$se <- signif(Sum$se, digits=3)
Sum

library(ggplot2)
pd <- position_dodge(.2)
ggplot(Sum,aes(x=OS, y=mean, color = OS)) + geom_errorbar(aes(ymin =
      mean - se,ymax = mean + se),width=.2,size=0.7, position=pd)+
      geom_point(aes(shape=OS), size=5, position=pd)+ theme_bw() +
      theme(plot.title = element_text(face="bold", hjust=0.5),
            axis.title = element_text(face="bold"),
            axis.text = element_text(face="bold"),
            plot.caption= element_text(hjust=0),
            legend.text = element_text(face="bold"),
            legend.title = element_text(face="bold"),
            legend.justification = c(1,0),
            legend.position="none") +
      ylab(expression("Time (m)")) +
      ggtitle("Time vs OS")

# 8. Gráfico bigotes con error estándar Scene:OS
Sum <- Summarize(Time ~ OS + Scene, data=Data, digits=3)
Sum$se <- Sum$sd / sqrt(Sum$n)
Sum$se <- signif(Sum$se, digits=3)
Sum

library(ggplot2)
pd <- position_dodge(.2)
ggplot(Sum,aes(x=Scene, y=mean, color = OS)) + geom_errorbar(aes(ymin =
      mean - se,ymax = mean + se),width=.2,size=0.7, position=pd)+
      geom_point(aes(shape=OS), size=5, position=pd)+ theme_bw() +
      theme(plot.title = element_text(face="bold", hjust=0.5),
            axis.title = element_text(face="bold"),
            axis.text = element_text(face="bold"),
            plot.caption= element_text(hjust=0),
            legend.text = element_text(face="bold"),
            legend.title = element_text(face="bold"),
            legend.justification = c(1,0)) +
      ylab(expression("Time (m)")) +
      ggtitle("Time vs Scene in function of OS")


# 9. Gráfico bigotes con error estándar Acc.Int:OS
Sum <- Summarize(Time ~ OS + Acc.Int, data=Data, digits=3)
Sum$se <- Sum$sd / sqrt(Sum$n)
Sum$se <- signif(Sum$se, digits=3)
Sum

library(ggplot2)
pd <- position_dodge(.2)
ggplot(Sum,aes(x=Acc.Int, y=mean, color = OS)) + geom_errorbar(aes(ymin =
      mean - se,ymax = mean + se),width=.2,size=0.7, position=pd)+
      geom_point(aes(shape=OS), size=5, position=pd)+ theme_bw() +
      theme(plot.title = element_text(face="bold", hjust=0.5),
            axis.title = element_text(face="bold"),
            axis.text = element_text(face="bold"),
            plot.caption= element_text(hjust=0),
            legend.text = element_text(face="bold"),
            legend.title = element_text(face="bold"),
            legend.justification = c(1,0)) +
      ylab(expression("Time (m)")) +
      ggtitle("Time vs Acc.Int in function of OS")

# 10. Pruebas T
# Prueba para OS
t_test_os <- pairwise.t.test(Data$Time, Data$OS, p.adjust.method = "BH")
# Prueba para Scene:OS
t_test_os_scene <- pairwise.t.test(Data$Time, Data$OS : Data$Scene, p.adjust.method = "BH")
# Prueba para Acc.Int
t_test_accint <- pairwise.t.test(Data$Time, Data$Acc.Int, p.adjust.method = "BH")
```

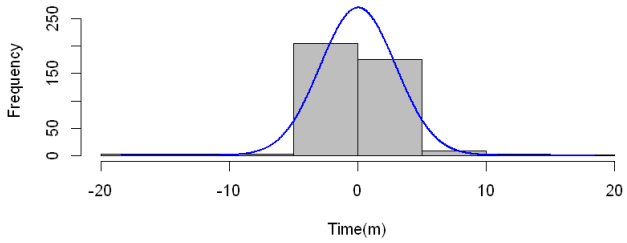
A data.frame: 9 × 4

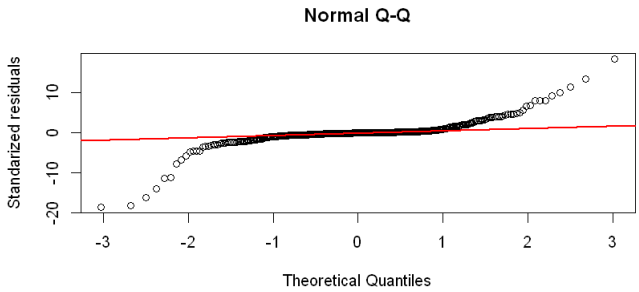
	OS	Scene	Time	Acc.Int
	<fct>	<fct>	<chr>	<fct>
1	Windows11	pavilion-day.pbrt	28.93	kdtree-volpath
2	Windows11	dragon-10.pbrt	33.35	kdtree-volpath
3	Windows11	killeroo-gold.pbrt	7.95	bvh-volpath
4	Windows11	dragon-10.pbrt	11.1	bvh-path
...	NA	NA	...	NA
397	Ubuntu-22-04-VM-Minimal	killeroo-gold.pbrt	6.64	bvh-path
398	Ubuntu-22-04-VM-Minimal	vw-van.pbrt	11.91	bvh-path
399	Ubuntu-22-04-VM-Minimal	killeroo-gold.pbrt	9.92	kdtree-volpath
400	Ubuntu-22-04-VM-Minimal	dragon-10.pbrt	11.48	bvh-path

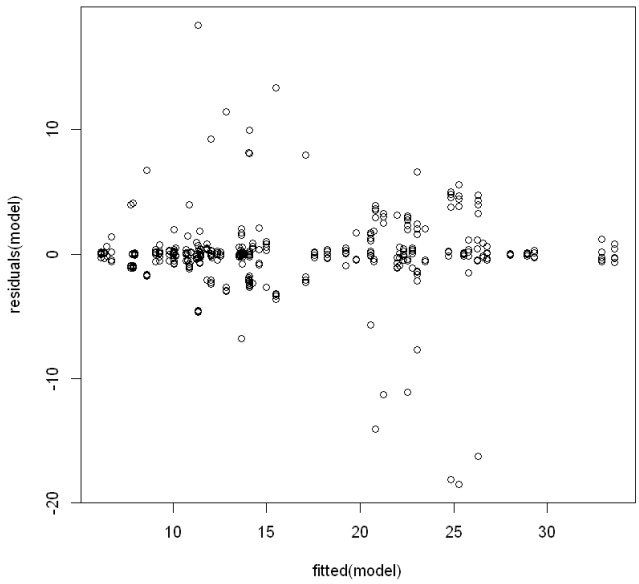
```
'data.frame':   400 obs. of  4 variables:
 $ OS     : Factor w/ 5 levels "Windows11","Ubuntu-22-04-VM-Minimal",..: 1 1 1 1 1 1 1 1 1 1 ...
 $ Scene  : Factor w/ 4 levels "pavilion-day.pbrt",..: 1 2 3 2 4 2 2 4 3 3 ...
 $ Time   : num  28.93 33.35 7.95 11.1 13.98 ...
 $ Acc.Int: Factor w/ 4 levels "kdtree-volpath",..: 1 1 2 3 2 2 4 4 3 1 ...
                       OS                    Scene          Time
 Windows11              :80   pavilion-day.pbrt :100   Min.   : 5.87
 Ubuntu-22-04-VM-Minimal:80   dragon-10.pbrt    :100   1st Qu.:10.17
 Ubuntu-22-04-WSL       :80   killeroo-gold.pbrt:100   Median :13.61
 Ubuntu-22-04-VM        :80   vw-van.pbrt       :100   Mean   :16.36
 Ubuntu-22-04           :80                            3rd Qu.:22.76
                                                       Max.   :34.43

          Acc.Int
 kdtree-volpath:100
 bvh-volpath   :100
 bvh-path      :100
 kdtree-path   :100
```

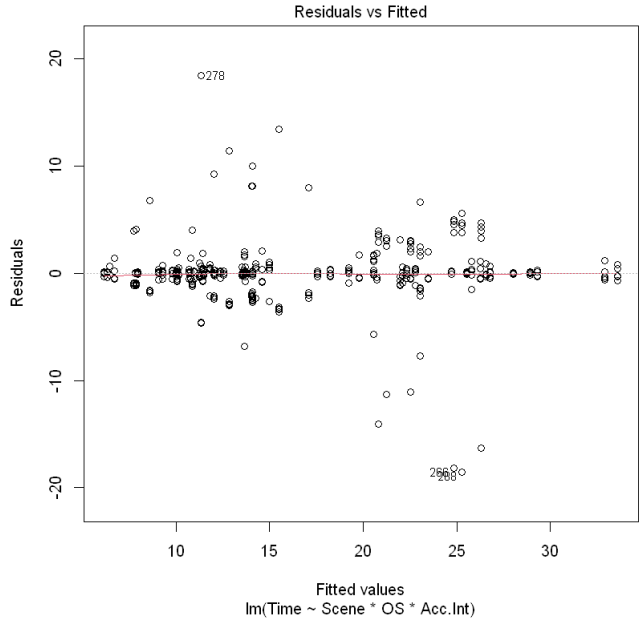


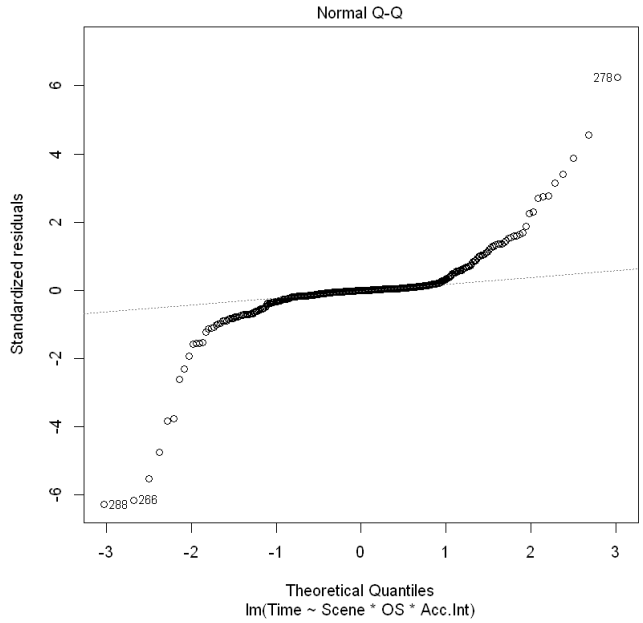

OS
Windows11
Ubuntu-22-04-VM-Minimal
Ubuntu-22-04-WSL
Ubuntu-22-04-VM
Ubuntu-22-04
Time(m)
12
14
16
18
20
22
kdtree-volpath
bvh-path
kdtree-path
Accelerator-Integrator

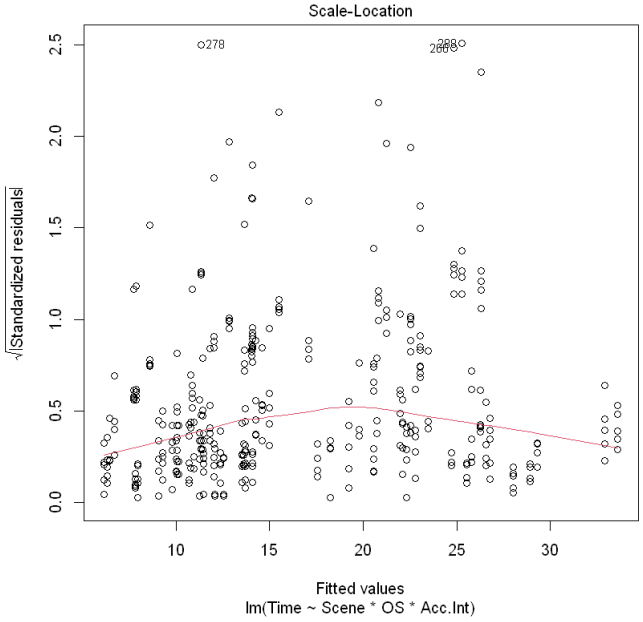

Frequency
0
50
150
250
-20
-10
0
10
20
Time(m)


Normal Q-Q
Standarized residuals
-20
-10
0
10
-3
-2
-1
0
1
2
3
Theoretical Quantiles


residuals(model)
-20
-10
0
10
10
15
20
25
30
fitted(model)


Residuals vs Fitted
Residuals
Fitted values
lm(Time ~ Scene * OS * Acc.Int)
278
266
288


Normal Q-Q
Standardized residuals
Theoretical Quantiles
lm(Time ~ Scene * OS * Acc.Int)
278
288
266


Scale-Location
√|Standardized residuals|
Fitted values
lm(Time ~ Scene * OS * Acc.Int)
278
288
266

A anova: 2 × 3

	Df	F value	Pr(>F)
	<int>	<dbl>	<dbl>
group	79	0.7474269	0.9396665
	320	NA	NA

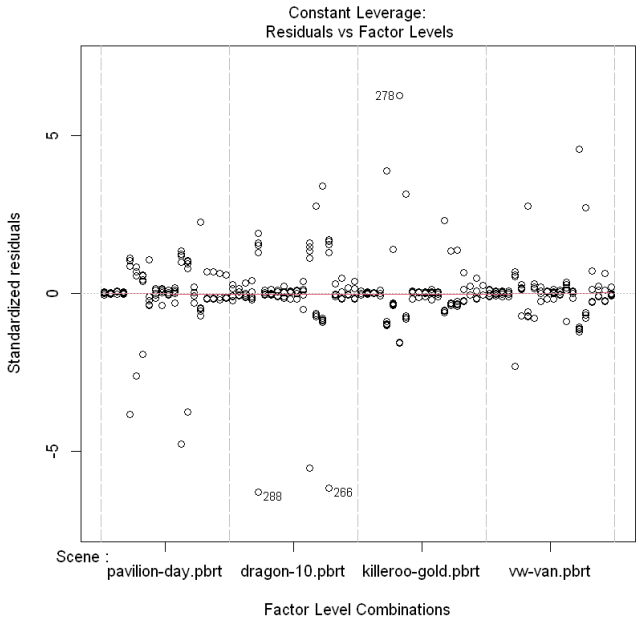
A anova: 8 × 4

	Sum Sq	Df	F value	Pr(>F)
	<dbl>	<dbl>	<dbl>	<dbl>
Scene	10765.5178	3	330.7342776	1.094224e-97
OS	761.1460	4	17.5377359	5.018005e-13
Acc.Int	2914.9651	3	89.5524861	4.293080e-42
Scene:OS	224.0382	12	1.7207050	6.127817e-02
Scene:Acc.Int	4183.9836	9	42.8462679	6.492352e-50
OS:Acc.Int	255.1001	12	1.9592726	2.739847e-02
Scene:OS:Acc.Int	267.8452	36	0.6857201	9.152851e-01
Residuals	3472.0378	320	NA	NA

A data.frame: 5 × 10

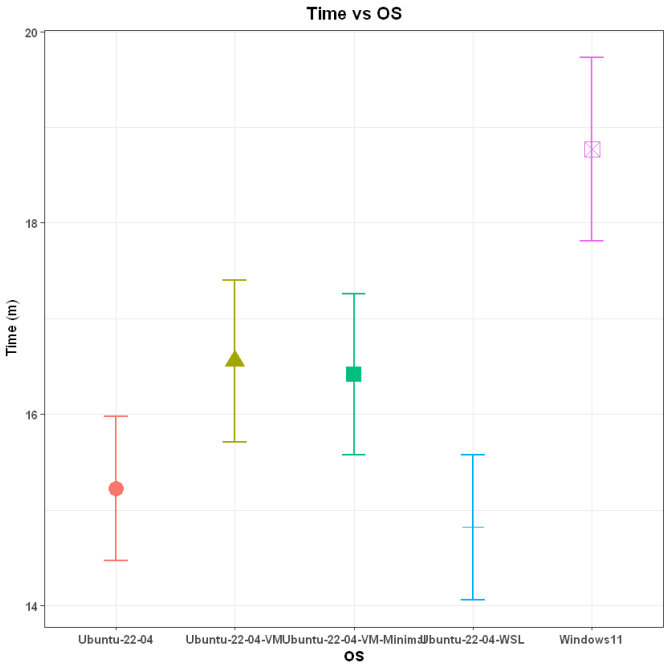
OS	n	mean	sd	min	Q1	median	Q3	max	se
<fct>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
Windows11	80	18.770	8.601	7.77	12.010	15.795	26.230	34.43	0.962
Ubuntu-22-04-VM-Minimal	80	16.419	7.509	6.64	11.018	13.665	22.625	30.84	0.840
Ubuntu-22-04-WSL	80	14.819	6.798	5.87	9.480	12.025	21.028	27.39	0.760
Ubuntu-22-04-VM	80	16.555	7.566	6.64	11.108	13.670	22.933	31.00	0.846
Ubuntu-22-04	80	15.224	6.761	6.15	9.992	13.285	21.990	27.44	0.756

```
Warning message:
"Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.
i Please use `linewidth` instead."
```



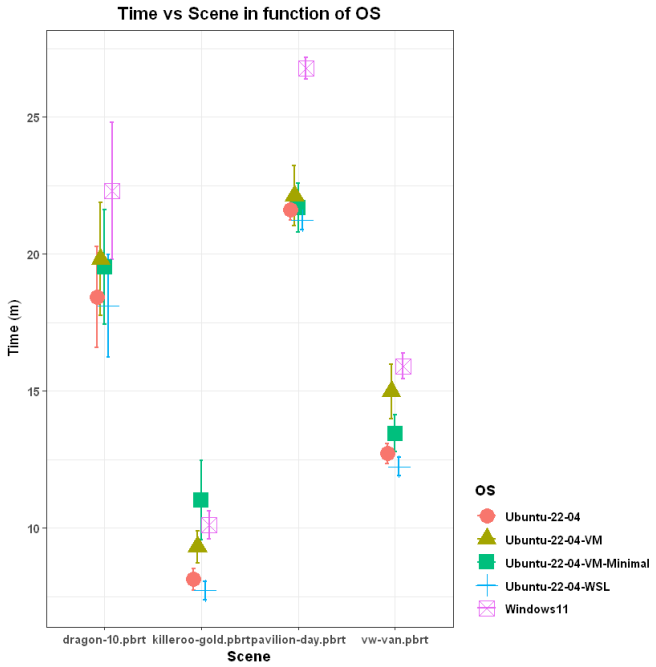
A data.frame: 20 × 11

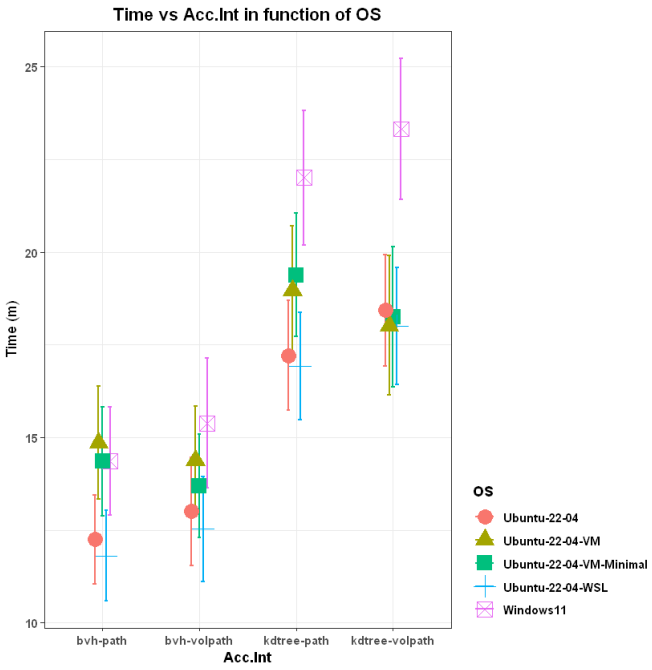
OS	Scene	n	mean	sd	min	Q1	median	Q3	max	se
<fct>	<fct>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
Windows11	pavilion-day.pbrt	20	26.784	1.774	24.57	25.285	26.790	28.258	29.00	0.397
Ubuntu-22-04-VM-Minimal	pavilion-day.pbrt	20	21.697	4.008	9.93	21.168	22.205	24.540	25.50	0.896
Ubuntu-22-04-WSL	pavilion-day.pbrt	20	21.220	1.515	18.32	20.235	21.235	22.613	23.23	0.339
Ubuntu-22-04-VM	pavilion-day.pbrt	20	22.126	4.979	6.79	21.548	22.650	24.778	29.66	1.110
Ubuntu-22-04	pavilion-day.pbrt	20	21.628	1.771	19.33	20.278	21.990	22.922	25.49	0.396
Windows11	dragon-10.pbrt	20	22.304	11.235	10.84	11.268	22.230	33.085	34.43	2.510
Ubuntu-22-04-VM-Minimal	dragon-10.pbrt	20	19.520	9.404	6.76	11.727	12.200	29.410	30.84	2.100
Ubuntu-22-04-WSL	dragon-10.pbrt	20	18.105	8.404	9.29	10.110	17.280	26.328	27.39	1.880
Ubuntu-22-04-VM	dragon-10.pbrt	20	19.814	9.232	6.71	11.732	17.150	29.593	31.00	2.060
Ubuntu-22-04	dragon-10.pbrt	20	18.430	8.210	9.97	10.280	18.970	26.300	27.44	1.840
Windows11	killeroo-gold.pbrt	20	10.094	2.278	7.77	7.878	9.940	12.328	12.73	0.509
Ubuntu-22-04-VM-Minimal	killeroo-gold.pbrt	20	11.008	6.434	6.64	6.787	9.670	9.990	29.74	1.440
Ubuntu-22-04-WSL	killeroo-gold.pbrt	20	7.713	1.532	5.87	6.315	7.485	9.270	9.50	0.343
Ubuntu-22-04-VM	killeroo-gold.pbrt	20	9.304	2.581	6.64	6.875	9.755	10.110	15.34	0.577
Ubuntu-22-04	killeroo-gold.pbrt	20	8.122	1.757	6.15	6.300	8.610	9.250	12.00	0.393
Windows11	vw-van.pbrt	20	15.898	2.095	13.39	13.898	15.795	17.785	18.59	0.468
Ubuntu-22-04-VM-Minimal	vw-van.pbrt	20	13.452	2.998	6.86	11.982	12.495	15.170	22.16	0.670
Ubuntu-22-04-WSL	vw-van.pbrt	20	12.237	1.488	10.15	11.008	12.025	13.660	14.25	0.333
Ubuntu-22-04-VM	vw-van.pbrt	20	14.977	4.418	11.91	12.328	13.670	15.322	28.91	0.988
Ubuntu-22-04	vw-van.pbrt	20	12.714	1.652	10.65	11.050	13.285	13.752	16.69	0.369



A data.frame: 20 × 11

OS	Acc.Int	n	mean	sd	min	Q1	median	Q3	max	se
<fct>	<fct>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
Windows11	kdtree-volpath	20	23.324	8.564	12.38	16.622	23.675	29.980	34.43	1.91
Ubuntu-22-04-VM-Minimal	kdtree-volpath	20	18.247	8.452	6.76	9.930	15.510	24.312	30.84	1.89
Ubuntu-22-04-WSL	kdtree-volpath	20	18.012	7.083	8.75	12.050	18.035	23.630	27.39	1.58
Ubuntu-22-04-VM	kdtree-volpath	20	18.021	8.388	6.79	10.150	15.635	24.573	31.00	1.88
Ubuntu-22-04	kdtree-volpath	20	18.429	6.715	9.25	13.312	19.340	24.942	27.44	1.50
Windows11	bvh-volpath	20	15.383	7.813	7.83	10.465	12.890	17.718	28.09	1.75
Ubuntu-22-04-VM-Minimal	bvh-volpath	20	13.690	6.243	6.74	11.318	12.120	13.330	25.50	1.40
Ubuntu-22-04-WSL	bvh-volpath	20	12.527	6.337	5.94	8.773	10.350	13.775	23.23	1.42
Ubuntu-22-04-VM	bvh-volpath	20	14.374	6.551	6.79	11.725	12.235	17.045	25.58	1.46
Ubuntu-22-04	bvh-volpath	20	13.008	6.531	6.29	9.432	10.990	14.890	25.49	1.46
Windows11	bvh-path	20	14.363	6.486	7.77	10.102	12.790	16.567	24.91	1.45
Ubuntu-22-04-VM-Minimal	bvh-path	20	14.354	6.596	6.64	11.367	11.925	21.695	29.74	1.47
Ubuntu-22-04-WSL	bvh-path	20	11.810	5.475	5.87	8.547	10.140	13.402	20.82	1.22
Ubuntu-22-04-VM	bvh-path	20	14.863	6.844	6.64	11.533	12.035	21.913	28.91	1.53
Ubuntu-22-04	bvh-path	20	12.246	5.388	6.15	9.512	10.645	14.967	22.57	1.20
Windows11	kdtree-path	20	22.009	8.109	11.80	16.030	21.575	27.320	34.09	1.81
Ubuntu-22-04-VM-Minimal	kdtree-path	20	19.386	7.443	9.59	13.992	20.880	26.058	29.60	1.66
Ubuntu-22-04-WSL	kdtree-path	20	16.927	6.434	8.50	12.420	16.120	20.870	26.91	1.44
Ubuntu-22-04-VM	kdtree-path	20	18.962	7.844	6.71	13.592	18.090	25.938	29.83	1.75
Ubuntu-22-04	kdtree-path	20	17.212	6.619	9.08	12.498	16.710	22.555	27.36	1.48




Time vs Acc.Int in function of OS
Time (m)
25
20
15
10
bvh-path
bvh-volpath
kdtree-path
kdtree-volpath
Acc.Int
OS
Ubuntu-22-04
Ubuntu-22-04-VM
Ubuntu-22-04-VM-Minimal
Ubuntu-22-04-WSL
Windows11

In [ ]: